CHAPTER 13

Conclusions and recommendations for action

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Introduction

> *"It is in the interest of all the world that climatic changes are understood and that the risks of irreversible damage to natural systems, and the threats to the very survival of man, be evaluated and allayed with the greatest urgency" (1).*
>
> *His Excellency Maumoon Abdul, Gayoom, President of the Republic of the Maldives*

These words were delivered in 1987 at the United Nations General Assembly on the Issues of Environment and Development. Although much has been learned about the expected impacts of climate change on ecosystems and people, and some important actions are emerging, much is still to be done to diminish further the gap between knowledge and action.

Global climate change of the magnitude and rate seen in the past hundred years is a relatively recent, unfamiliar threat to the conditions of the natural environment and human health. It is one of a set of large-scale environmental changes now underway, each reflecting the increasing impacts of human activities on the global environment (*2*). These changes, including: stratospheric ozone depletion; biodiversity loss; worldwide land degradation; freshwater depletion; and the global dissemination of persistent organic pollutants have great consequences for the sustainability of ecological systems, food production, human economic activities and human population health (*3*).

In turn, these global environmental changes are the result of a complex set of drivers. These include: population change (population growth, movement and rapid urbanization); unsustainable economic development (manifested in current production and consumption patterns); energy, agricultural and transport policies; and the current state of science and technology (*4*). Economic and technological developments have contributed to a remarkable improvement in the global health status since the industrial revolution. The unwanted side effect of this development has been a range of harmful changes to the environment, initially at local level but now extending to the global scale. Many of these large-scale environmental changes threaten ecosystems and human health. Indeed, scientists are concerned that current levels and types of human economic activities may be impairing the planet's life-support systems at a global level (*5*).

Various global environmental threats have been followed by concerted actions in the form of international conventions, global assessments and global agendas

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[3] World Meteorological Organization, Geneva, Switzerland.

BOX 13.1 Selected international conventions

Biodiversity

Convention on Biological Diversity (1992) and its Cartagena Protocol on Biosafety (2000) (http://www.biodiv.org).

Climate change

The United Nations Framework Convention on Climate Change (UNFCCC, 1992) and its Kyoto Protocol (1997) (http://www.unfccc.int).

Desertification

Convention to Combat Desertification (1992) (http://www.unccd.int).

Hazardous chemicals

Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (1998) (http://www.pic.int).

Hazardous wastes

Basel Convention on Transboundary Movements of Hazardous Wastes and their Disposal (1989) and its Protocol on Liability and Compensation (1999) (http://www.basel.int).

Ozone

Vienna Convention for the Protection of the Ozone Layer (1985) and its Montreal Protocol on Substances that Deplete the Ozone Layer (1987) (http://www.unep.org/ozone).

Persistent organic pollutants

The Stockholm Convention on Persistent Organic Pollutants (2001) (http://www.pops.int).

Wetlands

The Convention on Wetlands (commonly known as the Ramsar Convention 1971) (http://www.ramsar.org).

for action, with the support of many nations (Box 1). Some have been more successful than others; some need more time to reach consensus. All have a sense of urgency and need commitment by governments and people, at all levels.

The United Nations Conference on the Human Environment in 1972 reflected the major concerns of the times: chemical contamination, depletion of natural resources, environmental and social impacts of rapid urbanization and the threat of nuclear weapons. Its Declaration also acknowledged emerging concerns about rapid environmental change and potentially global threats as the result of human induced activities: "A point has been reached in history when we must shape our actions throughout the world with a more prudent care for their environmental consequences. Through ignorance or indifference we can do massive and irreversible harm to the earthly environment on which our life and well-being depend" (*6*).

Two decades later (1992) at the United Nations Conference on Environment and Development (the Earth Summit), traditional environmental problems were addressed along with a new set of problems: emerging global environmental threats. Thus, the Earth Summit not only gave rise to a plan of action for sustainable development towards the twenty-first century (Agenda 21, which included both well known and newer global threats) but also opened for signature the United Nations Framework Convention on Climate Change. Important agreements also were reached regarding the Convention on Biological Diversity (the conservation of biological diversity; the sustainable use of its components; and the fair and equitable sharing of the benefits from the use of genetic resources), and the Convention to Combat Desertification.

At its core, sustainability is about maintaining functional ecological and other biophysical life-support systems on Earth. If these systems decline, eventually human population health indices also will begin to turn down. Technology can buy time, it is possible to buffer against immediate impacts and indeed extract more "goods and services" from the natural world, but nature's bottom-line accounting cannot be evaded. That is, the continuing health of human populations depends on not exceeding (or staying within) the environment's "carrying capacity". The global climate system is a prime determinant of ecological sustainability and thus of Earth's capacity to sustain healthy human life. Viewed in this way, the sustainability of human population health becomes a central criterion in the transition to sustainable development (*7*).

The Rio Declaration on Environment and Development at the Earth Summit (*8*) adopted the precautionary principle to protect the environment. This principle states that where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. The precautionary principle has been incorporated within the United Nations Framework Convention on Climate Change. This principle addresses the dilemma that while uncertainties still surround climate change, to wait for full scientific certainty before taking action would almost certainly be to delay actions to avert serious (perhaps irreversible) impacts until they are too late. This precautionary approach is well understood in public health (*9*). As stated by WHO's Director-General, Dr. Brundtland, in this context, "having unintentionally initiated a global experiment, we cannot wait decades for sufficient empirical evidence to act. That would be too great a gamble with our children's future" (*10*).

The First World Climate Conference, sponsored by The World Meteorological Organization (WMO) in 1979, recognized climate change as a problem of increasing significance. The WMO also established the World Climate Programme in that year. In 1988 the United Nations Environment Programme (UNEP) and WMO established the Intergovernmental Panel on Climate Change (IPCC). The Panel was given a mandate to assess the state of existing knowledge about the climate system and climate change; the environmental, economic, and social impacts of climate change; and the possible response strategies. Its First Assessment Report was released in 1990, the latest (Third Assessment Report, or TAR) in 2001.

The ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) is the stabilization of greenhouse gas concentration in the atmosphere, achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change. It accepts that some change is inevitable and therefore adaptive measures are required. Impacts will be felt on ecosystems

BOX 13.2 The Kyoto Protocol

The most important instrument for potential internationally co-ordinated policy on climate change mitigation is the Kyoto Protocol. This was adopted at COP-3 in December 1997, containing stronger emissions-related commitments for developed countries. By arresting and reversing the upward trend in greenhouse gas emissions that started in these countries 150 years ago, the Protocol promises to move the international community one step closer to achieving the Convention's ultimate objective of preventing "dangerous anthropogenic interference with the climate system".

The Protocol sets legally binding targets and timetables for cutting developed country emissions (to six main greenhouse gases, the most important being CO_2). Moreover, the Protocol ensures that emission cuts are verifiable.

and directly or indirectly on human health. Such impacts include agriculture and food security; sea level rise and coastal areas; biological diversity; water resources; infrastructure; industry; and human settlements. The Kyoto Protocol to the UNFCCC strengthens the international response to climate change (Box 2).

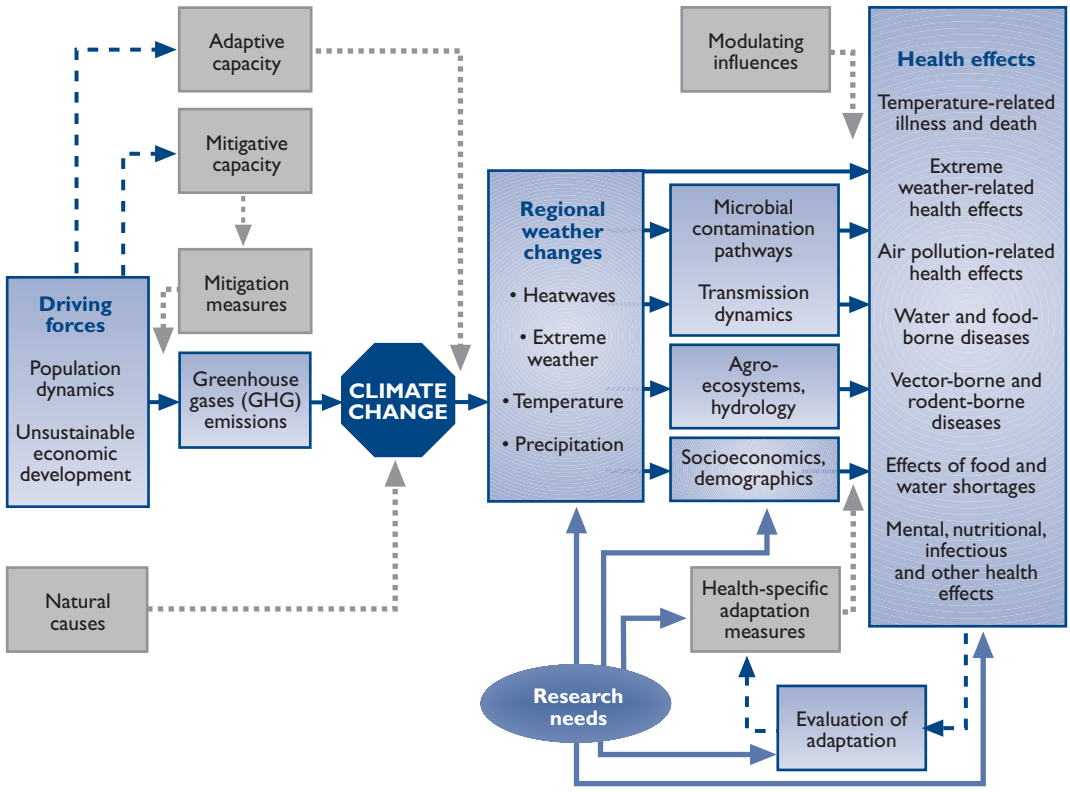
The evidence relating to the existence of human-induced global climate change has become compelling: the IPCC's Third Assessment Report concluded that human-induced warming has begun. Global average temperature is rising faster than at any time in the last 10000 years, and there is new and stronger evidence to indicate that most of the warming observed over the last 50 years is due to human activities (*11*). This has been associated with climate-attributable changes in simple physical and biological systems including: the retreat of glaciers; thinning of sea ice; thawing of permafrost; earlier nesting and egg-laying by birds; pole-wards extension of insect and plant species; and earlier flowering of plants.

This general scientific elucidation of climate change has sensitized the general public and policy-makers to the potential that climate change will cause various adverse health impacts. While the full range of projected climate change would have both beneficial and adverse effects, adverse effects will dominate if the larger climate changes and rates of change occur. That adds an extra dimension of concern and weight to the international discourse on this topic.

Figure 13.1 illuminates the basic components of the complex process: global driving forces, environmental changes, human exposures and the better-known, potential health effects. Upstream actions (mitigation mechanisms to reduce emissions of GHGs) are the most appropriate and effective but climate change is a process that will take many decades to control and reverse. Co-ordinated adaptation mechanisms will be required from all sectors, including health. This is a new challenge for the health sector, and research needs are many and large: better understanding of human exposures in this context; contamination pathways or transmission dynamics; expected and lesser-known health impacts; and adaptation options and their evaluation. Table 13.1 gives examples of priority research areas for the examples of health effects outlined in Figure 13.1.

As a response to the requirements stated in Agenda 21 and the UNFCCC, a number of organizations carrying out significant climate related activities jointly developed the Inter-Agency Committee on the Climate Agenda (IACCA). WHO, WMO and UNEP jointly contribute towards the health aspects of the Climate

FIGURE 13.1 Climate change and health: pathway from driving forces, through exposures to potential health impacts. Lines under research needs represent input required by the health sector. *Source: adapted from reference (12).*



Agenda within the general field of "climate impact assessment and response strategies to reduce vulnerability". The second IACCA session, held in Geneva in 1998, proposed the establishment of an Inter-Agency Network on Climate and Human Health, with a secretariat coordinated by WHO. Joint activities of the Interagency Network between WHO, WMO and UNEP began in 1999. The collaborative work focuses on three areas: capacity building, information exchange and research promotion (Box 3).

Conclusions and recommendations

Several major conclusions emerge from this book. They are listed below in the order of the chapters from which they emerge, not in order of priority. All are selected for their global relevance:

Climate related exposures

Climate is an important determinant for human health. Both weather and climatic variables can be seen as human exposures that directly or indirectly impact on human health. Moreover, these are not expected to remain constant, and overall likely to increase their impacts on human health.

TABLE 13.1 Priority health research areas for different risk factors resulting from climate change.

Risk Factors	Health effects	Priority research areas
Extreme heat or cold; Stagnant air masses	Temperature related illness and death	Improved prediction, warning and response
Strong precipitation variability	Extreme weather related health effects	Assessment of past impacts and effectiveness of warnings
Local air pollution; Stagnant air masses	Air pollution related health effects	Combined effects of climate factors and air pollution; Weather related allergens
Precipitation; Water temperature	Water-borne and food-borne diseases	Climate and marine-related diseases; Climate, land-use impacts on water quality and health
Temperature, humidity, precipitation	Vector-borne and rodent-borne diseases	Climate related disease transmission dynamics; Improved surveillance
Temperature, water scarcity, land use	Nutritional deficiencies	Health and agricultural sector adaptation strategies
Extreme events, population displacement	Mental health	Assessment of past interventions related to emergencies and population displacement

Source: adapted from reference 12.

BOX 13.3 Inter-agency network on climate and human health

WHO, WMO and UNEP collaborate in:

Capacity building activities: assisting Member States in: a) undertaking national assessments of climate-induced human health impacts; b) determining and meeting capacity-building and research needs in order to identify and address priority areas; c) identifying and implementing adaptation strategies and preventive and mitigating measures, designed effectively to reduce adverse health impacts.

Information exchange: a) provision of information to Member States, national and international training and research institutions, and the public at large, on the state-of-the-art in the global research effort on climate and health interactions, their consequences for population health and for public health response; b) fulfilling "clearing house" functions to ensure free access to information including databases needed for research on climate variability and climate change on human health in developing countries.

Research promotion: a) to serve as the UN-based lead group of institutions and experts for the guidance of research programmes on the human health implications of climate and of global environmental change, including the impacts of climate variability, climate change and stratospheric ozone depletion.

The IPCC's Third Assessment Report concluded that most of the warming observed over the past 50 years is attributable to human activities. This implies that reversing this trend also will need to be the result of human actions. However, it is known that human influences will continue to change atmospheric composition throughout the twenty-first century. Global average temperature is projected to rise by 1.4 to 5.8 °C from 1990 to 2100. Global climate change will not likely be spatially uniform, and is expected to include changes in temperature and the hydrologic cycle.

Studying the natural complexities of weather and climate variability in relation to health outcomes offers unique challenges. Weather and climate can be

summarized over various spatial and temporal scales. The appropriate scale of analysis will depend on the study hypothesis. Each study needs to define the exposure of interest and the lag period between exposure and effect. Analogue studies are one means of estimating risks of climate sensitive diseases for future climate change although the predictive value of these studies may be limited. Future events may differ from historical events and the extent of vulnerability of a population changes over time. For these and other reasons, scenario-based modelling is used to project what might happen under different climate conditions.

Current knowledge is limited in many areas. Research is needed, particularly in the following:

- developing innovative approaches to analysing weather and climate in the context of human health;
- setting up long-term data sets to answer key questions, such as whether infectious diseases are likely to change their range;
- improved understanding of how to incorporate outputs from multiple Global Climate Models into health studies better to address the range of uncertainties associated with projected future health impacts.

One important consideration for researchers is the ongoing change in the climate baseline. Many archives of meteorological data contain baseline parameters, or climatological normals, based on the average data for three decades, which are re-calculated every 10 years. While such archives may have desirable densities in terms of time and space, analysis methods need to take into account the changing climate baseline such archives provide to avoid erroneous, potentially conservative, conclusions. The WMO addresses this by maintaining the Climatological Standard Normals (CLINO) (*13*). Re-computed each 30 years, the CLINO provide a stable baseline throughout that period. As all CLINO datasets reflect the same input period, the differences in values between observing locations reflect the differences in climate rather than differences caused by non-common time periods.

Reaching consensus on the science

The science of climate change increasingly has achieved consensus among scientists, in particular through the assessments of the IPCC. Although much research still is needed on climate change and health links, there is increasing evidence that human health will be affected by climate change in many and diverse ways.

Higher temperatures and changes in precipitation and climate variability are likely to alter the geographical range and seasonality of some climate sensitive vectors—potentially extending the range and season of some vector-borne diseases, contracting them for others. Heavy rainfall and increases in water surface temperature are associated with contamination of marine and fresh water with water-borne diseases. Countries lying in the tropics are highly vulnerable to climate sensitive infectious diseases and are likely to experience greater impacts than those in the colder regions. The greatest increases in thermal stress are forecasted in the mid to high latitude cities especially in populations with non-adapted architecture and no air conditioning. There has been increasing frequency of natural disasters in certain regions since the 1990s; these could continue to increase with a higher frequency and severity.

Knowledge is still limited in many areas, for example:

- the contribution of short-term climate variability to disease incidence needs further research;
- early warning systems for prediction of disease outbreaks, heatwaves and other extreme events need to be developed further and validated;
- there is a risk that frequent extreme events may lead over time to weakened adaptive capacity. To evaluate and correct this deficiency methods are needed to carry out national and regional level assessments for adaptive capacity.

Remaining challenges for scientists

In many respects, climate change is a different kind of problem to those that health scientists are accustomed to studying. To respond, new approaches and thoughtful recasting of existing scientific methods are needed. For example, to appreciate the possible impacts of climate change it is necessary (although not sufficient) to understand the present-day effects of weather and climate variability on health. From this understanding, and given the rate and extent of global climate change, there may be opportunities to study directly the early effects on human health. These impacts will depend largely on how successfully human societies can adapt to this threat. Processes of adaptation therefore comprise a key research area in their own right.

Further, a particular challenge is posed by uncertainties. Conventional quantitative risk assessment, based on well-documented risks in today's world and applied to existing population exposure profiles, can yield reasonable precision: that is, statistical and situational uncertainties often can be greatly reduced. However, forecasting future risks to health from the complex processes of large-scale environmental change entails an unusual range of uncertainties (*14*).

Uncertainties in climate change science come from many sources. Some depend on data or arise from uncertainties about the structure of models or their key parameter values, some result from differing projections of social, demographic and economic futures, others reflect divergence of values and attitudes. The precautionary principle assumes importance because of these uncertainties in forecasting the consequences (health and otherwise) of climate change. Where scientific knowledge is uncertain and the situation complex, and where there is a finite (though perhaps small) risk of serious (possibly irreversible) damage to population health, then preventive action should be taken. That is, in such potentially serious situations, scientific uncertainty does not justify policy inaction. Some key areas to address in current and future research include:

- identifying areas where first effects of climate change on human health will be apparent;
- improving estimates of climate change impacts by a combination of anticipated trends in adaptive capacity and climate scenarios;
- identifying the most helpful ways of expressing uncertainties associated with studies of climate change and health.

Extreme climate events

It can be difficult to understand climate change's relevance to health. The impact of a small magnitude change in mean temperature can seem insignificant as a respectively small magnitude change in sea level. The importance of such

changes is in the way that they can indicate shifts in the distribution of health-relevant climate elements, especially their extreme values. For example, an increase in the mean temperature implies that new record high temperatures are likely but does not imply a corresponding change in the range between hottest and coldest temperatures (*11*) that comes with an increase in the variability. Other characteristics become apparent when both the mean and the variability change.

Analysis of the potential extremes associated with climate change is both complex and important: extreme weather conditions influence the health outcomes that the public health community will have to handle. The IPCC's Third Assessment Report projected changes in extreme climate events that include higher maximum temperatures; more hot days and heatwaves; more intense precipitation events; increased risk of drought; increase in wind and precipitation regimes of tropical cyclones (over some areas); intensified droughts and floods with El Niño events; and increased variability in Asian summer monsoon precipitation.

In assessing future health impacts, analogue studies of extreme events and human health can provide important clues about the interactions between climate, ecosystems and human societies that may be triggered by future climate trends. Localized effects of simple climate extremes are readily quantifiable in many situations. This is not the case for complex climate extremes although these would provide important qualitative insights into these relationships, and the factors affecting population vulnerability, and thus be of greatest value for public health.

There is good evidence of associations between important communicable diseases and climate on several temporal and geographical scales. The increasing trend of natural disasters is due partly to more complete reporting, partly to an increase in population vulnerability. Poverty, population growth and migration are major contributory factors affecting this vulnerability. Especially in poor countries, the impacts of major vector borne diseases and disasters can limit or even reverse improvements in social development. Research gaps to be addressed include:

- further modelling of relationships between extreme events and health impacts, especially in poor countries;
- improved understanding of factors affecting vulnerability to climate extremes;
- assessment of the effectiveness of adaptation measures in different settings.

Infectious diseases

Indirectly transmitted infectious diseases (e.g. via insect vectors or water) are highly susceptible to a combination of ecological and climatic factors because of the numerous components in their transmission cycles, and the interaction of each of these components with the external environment. Insights specifically related to climate changes' influence on infectious diseases can be derived from past disease epidemics and seasonal fluctuation; long term disease trend analysis; and predictive models capable of estimating how future scenarios of different climatic conditions will affect the transmissibility of particular infectious diseases. Over the past 30 years, observed intensification of El Niño in the Bay of Bengal paralleling increasing proportions of cholera cases may be one of the first pieces of evidence that warming trends are affecting human infectious diseases (*15*, *16*).

Pathways through which weather conditions affect infectious diseases are variable and far greater than simply warmer temperatures. Precipitation extremes, humidity, and sea level change all can influence particular diseases. Certain moderating factors are important in examining how climate affects disease. These include socio-demographic influences such as human migration and transportation, drug resistance, and nutrition; as well as environmental influences such as deforestation or habitat fragmentation, agricultural development and water projects, biodiversity loss, and urbanization.

There remain many research and data needs. Disease incidence data is needed to provide a baseline for epidemiological studies. The lack of precise knowledge of current disease incidence rates makes it difficult to comment about whether incidence is changing as a result of climatic conditions. Research teams should be international and interdisciplinary, including epidemiologists, climatologists and ecologists to assimilate the diversity of information from these respective fields. The MARA project (*17*) serves as an excellent example for a useful validated predictive malaria model. Incorporating socioeconomic understanding of the adaptive capacity for societies affected by health outcomes of climate change will help predict population vulnerability, thereby optimizing preventive policies.

The burden of disease

It is not easy to assess and evaluate the risks posed to population health by global climate change. For a start, the empirical evidence implicating recent trends in regional and global climate in altered health outcomes is sparse. More generally, incomplete knowledge of how changes in climatic conditions affect a range of health outcomes makes it impossible to predict with confidence the range, timing and magnitude of likely future health impacts of global environmental changes. In spite of these limitations, estimation of the potential burden of disease due to climate change would help decision-makers to assess the potential magnitude of the problem (in human health terms) and assist the decision-making process concerned with adaptation. Considering only better-studied climate and health causal relationships, 150 000 deaths and 5.5 million DALYS can be attributed to climate change in 2000 (*18*).

Under conservative assumptions, the best models currently available indicate potential increases in the risk of diarrhoea, malaria, dengue, malnutrition, deaths and injuries from flooding, and heat-related mortality in tropical countries. These would be large enough to constitute a significant public-health impact within the next 30 years. Although there are predictions of some benefits of climate change in terms of reduced cardiovascular and respiratory mortality associated with low winter temperatures, mainly at higher latitudes, probably these will be small compared to negative effects elsewhere. The risks are heavily concentrated in populations of poorer tropical regions, mainly because poor socioeconomic conditions and infrastructure offer less protection against increased risks. Unless measures are taken to reduce overall risks in these populations, there will be unequal impacts on the health of the poor and marginalized groups.

Although the impacts potentially are large, estimates remain imprecise due to the uncertainties around climate predictions, climate-health relationships and possible future adaptation. Models that are driven mainly by changes in precipitation (inland flooding and malnutrition) are particularly uncertain. Key research gaps remain. There is a need, for example, for all impact models to be based on larger baseline datasets from a wider range of climate and socioeco-

nomic conditions, and to be validated routinely against past and present disease distributions. More quantitative measures of adaptation and vulnerability also are needed in order to give better estimates of the degree to which potential risks of climate change are likely to be offset, or exacerbated, by changing socioeconomic conditions and biological adaptation. Improved probabilistic representation of all sources of uncertainty around predictions, including climate scenarios, disease-climate relationships and future adaptation is needed. There is also a need for improved methods of estimating the health impacts of changes in the frequency of extreme events and indirect causal pathways (e.g. population displacement due to flooding) which are difficult to model quantitatively.

Stratospheric ozone depletion, climate change and health

Stratospheric ozone depletion essentially is a different process from climate change. However, the phenomenon of the climate's greenhouse-warming shares many of the chemical and physical processes involved in the depletion of stratospheric ozone (*19*). Some greenhouse gases contribute to stratospheric ozone destruction. Agreements among nations (Montreal Protocol) have achieved reductions in ozone-depleting gases and it is expected that stratospheric ozone depletion will begin to decline in a decade or so. With all other sources assumed constant, the recovery of stratospheric ozone is expected to be underway by the second quarter of this century, and should be substantially complete by the third quarter. Unfortunately for climate change, that result is not all positive. Substitutes for the CFCs are known to contribute to greenhouse-warming, confirmed by global observations. Another confounding effect is that as ozone depletion acts to cool the climate system, ozone recovery is actually expected to contribute to climate warming.

"Failure to comply with the Montreal Protocol and its amendments would significantly delay or even prevent the ozone layer's future recovery jeopardizing, among others, public health." (*20*). A review of the evidence has been presented, for three main categories of health impact: skin cancers (adverse impact); eye disorders (adverse impact); immune-related processes and disorders (mixed impact—some adverse, some potentially beneficial). The epidemiological evidence for causation is best for skin cancers, less consistent for eye disorders and incomplete for immune-related disorders. Further research is required to understand this important risk factor. With knowledge of the changing climate (in addition to information and education campaigns in countries) patterns of individual and community sun-seeking and sun-avoiding behaviour will change, variably, around the world with consequent impacts on the received personal doses of ultraviolet radiation.

National assessments

Several countries, developed and developing, have undertaken national assessments of the potential health impacts of climate change that provide important information about future impacts on vulnerable areas and populations. However there is a need to improve and standardize the health impact assessment tools and methods. Quantitative epidemiological methods can allow some estimation of the range of magnitude of potential impacts, but the uncertainties surrounding those estimates are, so far, poorly described. Health impact assessments should provide information for, or feed into the process of, the UNFCCC national

communications and other climate change assessments, strategies or action plans.

Much remains to be done: few comprehensive national assessments have been undertaken, even fewer in the most vulnerable populations and countries. Assessments in these populations would require some basic research on climate and health relationships, particularly in key areas such as diarrhoeal disease, vector-borne disease and malnutrition. More accurate climate information at the local level, particularly on climate variability and extremes, also is a pre-requisite for impact assessment. Methods and tools for such assessments are still being developed.

Monitoring climate change impacts on human health

Climate change is likely to cause incremental changes in the frequency or distribution of diseases that also are affected by several other factors. In their report on malaria early warning systems Thomson and Connor stressed that the commonest causative factor in malaria epidemics is "abnormal meteorological conditions, which temporarily change the ecological equilibrium between host(s), vector(s) and parasite(s)" (*21*). Monitoring to assess climate-change impacts on health therefore requires data gathering coupled with analytical methods for quantifying the climate-attributable part of such diseases.

Monitoring and surveillance systems in many parts of the world currently are unable to provide data on climate-sensitive diseases (e.g. diarrhoea or vector-borne diseases) that are sufficiently standardized and reliable to allow comparisons over long time periods or between locations. Some aspects of disease systems (e.g. seasonality of biting patterns of disease vectors) are likely to be affected by climate and little else. Standardized long-term monitoring of such indicators could provide direct evidence of climate-change impacts on health. For the majority of impacts, however, simple long-term measurement of climate and disease may be uninformative as there will be many alternative explanations for any observed trends. In such cases, evidence on short-term meteorology-disease relationships applied to measured change in climate can be used as an indirect means of estimating climate change-related impacts on health. In addition, long-term surveillance should encompass variables that may confound observed associations between climatic changes and disease incidence.

Current research gaps include the need for more standardized surveillance of climate-sensitive health states, especially in developing countries. This is an argument for strengthening systems designed to meet current needs rather than creating new systems specifically to detect climate change impacts on human health. Also there is a need to facilitate both access to health data (especially from developing countries) and its linkage to information on climate and determinants of vulnerability.

Adapting to climate change

Since changes in the world's climate are occurring already and will continue in future decades, if not centuries, there is now a clear need for adaptation policies to complement mitigation policies. Efficient implementation of adaptation strategies can significantly reduce adverse health impacts of climate change.

Outside the health sector, adaptation options for managed systems such as agriculture and water supply generally are increasing because of technological

advances. However, many developing countries have limited access to these technologies, appropriate information, finance or adequate institutional capacity. The effectiveness of adaptation strategies will depend upon cultural, educational, managerial, institutional, legal and regulatory practices that are both domestic and international in scope. In order to adapt for health impacts there is a critical general need for a sound and broadly-based public health infrastructure (including environmental management, public education, food safety regimes, vaccination programmes, nutritional support, emergency services and health status monitoring). This must be supplemented by health-directed policies in other sectors, including transport, urban planning, industry, agriculture, fisheries, energy, water management and so on.

Human populations vary in their vulnerability (or susceptibility) to certain health outcomes. The vulnerability of a population depends on factors such as population density, level of economic development, food availability, local environmental conditions, pre-existing health status and the availability of public health-care. It also depends on various structural and politically determined characteristics. Adaptive capacity in health systems varies among countries and socioeconomic groups.

The poorest groups in the poorest countries have the least ability to cope with climate change. Poor populations will be at greatest health risk from climate change because of their lack of access to material and information resources and because of their typically lower average levels of health and resilience (nutritional and otherwise). Long-term improvement in the health of impoverished populations will require income redistribution, increased employment opportunities, better housing and stronger public health infrastructure. Services with a direct impact on health, such as primary care, disease control, sanitation and disaster preparedness and relief, also must be improved. Development plays an important role in determining the adaptive capacity of communities and nations; enhancing adaptive capacity is necessary to reduce vulnerability. The reduction of socioeconomic vulnerability remains a top priority.

Implementation of adaptation measures usually will have near-term as well as future benefits due to reduction in impacts associated with current climate variability. In addition, adaptation measures can be integrated with other health objectives and programmes. For example, basic adaptation to climate change can be facilitated by improved environmental and health monitoring and surveillance systems. Basic indices of population health status (e.g. life expectancy) are available for most countries. However, disease (morbidity) surveillance varies widely depending on locality and the specific disease. To monitor disease incidence or prevalence (which may often provide a sensitive index of impact), low-cost data from primary care facilities could be collected in sentinel populations.

Although many actions need to be implemented with some urgency, decision-makers will benefit from research that answers specific questions. There is a key need for research on barriers and opportunities for enhancing adaptive capacity in order to protect human health, as well as potential interactions with ongoing development projects and programmes. Research also is needed on the processes of "adaptation decision-making", including identifying the roles and responsibilities of individuals, communities, nations, institutions and the private sector in adaptation. In addition, research on the costs and effectiveness of autonomous and planned adaptation measures is needed to assist in evaluating adaptation options.

Responses: from science to policy

It is clear that the magnitude and character of the problem of global climate change is such that a community-wide understanding and response is required, albeit guided by policy-makers provided with comprehensive advice from the international scientific community. Policy-focused assessment is a valuable process for providing timely and useful information to policy-makers, resource managers and other stakeholders in the public health community. Such assessments have already influenced—and are continuing to influence—policy and resource management decisions of interest to the public health community. A successful policy-focused assessment of the potential health impacts of climate change should have several key characteristics. These include the following:

- multidisciplinary assessment team;
- each assessment to answer in a timely fashion questions asked by stakeholders in the public health community;
- evaluation of risk management adaptation options;
- identification and prioritization of key research gaps;
- characterization and explanation of uncertainties and their implications for decision-making;
- development of tools in support of decision-making processes.

In addition, care must be taken to respect the boundary between assessment and policy formulation. Policy decisions are based on scientific assessments but also should include other considerations that reflect societal values (e.g. equity considerations) and other factors that affect decision-making (e.g. political feasibility).

The existence of scientific uncertainties about climate change and its potential health impacts does not preclude policy-makers from taking actions in anticipation of the health impacts of climate change. There are numerous examples in public health where improvements in health were achieved through effective actions before full scientific evidence was produced. Perhaps one of the most cited examples is that of John Snow's investigation and actions to stop a cholera epidemic in London, in 1854, a time when there were widely divided opinions on the causes of infectious diseases. Applying the yet unnamed precautionary principle, Snow managed to convince the relevant authorities to close down the water pump he identified as the source of the epidemic. The words of another famous epidemiologist note that action need not follow comprehensive scientific proof: "All scientific work is incomplete—whether it be observational or experimental. All scientific work is liable to be upset or modified by advancing knowledge. This does not confer upon us a freedom to ignore the knowledge that we already have, or to postpone the action that appears to demand at a given time" (*9*).

Numerous research questions about the potential impacts of climate change on human health have been identified. These need to be assessed and prioritized in order to be able to answer clearly the most important research gaps in each particular case and location. There is also an urgent need to perform assessments of adaptation strategies to reduce the risks to public health from climate change. For each adaptation option, assessments must evaluate the costs, benefits, effectiveness (in practice), barriers to implementation and risks of maladaptation. Finally better decision-support tools must be identified or developed to help

public health officials make decisions under uncertainty, given available assessment results.

Concluding remarks

International agreements to deal with global environmental issues such as climate change should invoke the principles of sustainable development proposed in Agenda 21 and the UNFCCC. These include the precautionary principle described earlier, the principle of costs and responsibility, implying that the cost of pollution or environmental damage should be borne by those responsible, and that of equity. Considerations of equity or fairness can apply within and between countries and over time (between generations). Equity implies having equal or similar opportunities, allowing all to maintain an acceptable level of living conditions or quality of life. The balance of benefits and costs of climate change, for example, is likely to differ between affluent communities in wealthy countries and marginal populations in poor countries, and between current generations (some may benefit from early stages of warming) and future generations (costs will outweigh benefits, if forecast warming trends continue). Box 4 shows how these key principles are described in Agenda 21 and UNFCCC.

BOX 13.4 Key principles in Agenda 21 and UNFCCC

Precautionary approach

Agenda 21:
In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

UNFCCC:
The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost.

Costs and responsibility

Agenda 21:
National authorities should endeavour to promote the internationalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment.

UNFCCC:
The Parties should protect the climate system for the benefit of present and future generations of humankind on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed countries should take the lead in combating climate change and the adverse effects thereof.

Continued

Equity

Agenda 21:
The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations.

UNFCCC:
The Parties should protect the climate system for the benefit of present and future generations of humankind on the basis of equity.

Adherence to these principles would make a substantial contribution towards the prevention of any future global environmental threat and the reduction of existing ones. As climate change processes already are underway, efforts also must focus on assessing current and future vulnerabilities and identifying necessary interventions or adaptation options. Adaptation has the potential to reduce adverse effects of climate change but is not expected to prevent all damages (22). Therefore, early planning for health is essential to reduce, hopefully avoid, near future and longer-term health impacts of global climate change. The optimal solution, however, is in the hands of governments, society and every individual—a commitment for a change in values to enable a full transition to sustainable development.

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